MISSION DESIGN FOR THE MARS ENVIRONMENTAL SURVEY

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by

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INTRODUCTION

On September 25, 1992, the United States made the latest step in the exploration of Mars with the launch of the Mars Observer mission. The next logical step in this exploration is to go beyond remote sensing from orbit to perform in situ measurements on the Martian surface. The Mars Environmental Survey (MESUR) mission is planned to be a network of 16 globall y distributed landers that will operate concurrently for at least one Martian year. The scientific goals of the mission arc to make long term measurements of the meteorology and seismology of Mars. In addition, observations will be made on the local geology and geochemistry of the terrain at each landing site.

Network missions have been studied in various forms for the last fifteen years. The MESUR concept, as original] y developed by the Ames Research Center [1], uses an evolutionary approach to emplace the network, The network landers arc delivered in groups of four or eight during the 1999, 2001 and 2003 Earth-Mars launch opportunities. The landers are designed to be launched four at time on a Delta 7925, and then each is flown separately to Mars. The landers enter the Martian atmosphere direct from the hyperbolic approach trajectory, using an aeroshell as the primary aerodynamic decelerator. Although this concept has some merit, it is only one possible network scenario. A mission architecture study has been initiated at JPL to study different approaches for achieving the network mission objectives.

One conclusion that has already been drawn from this study is that a precursor to the full net work mission would be extreme] y useful. This precursor would help accelerate the start of the project, allow for some early scientific return, and perform some of the basic technology demonstration required for MESUR. in view of these advantages, NASA has decided to schedule the MESUR Pathfinder mission for launch in 1996. Pathfinder is envisioned as a very low cost, short track development mission that would deliver onc lander to Martian surface. Only a small fraction of the complete network science could be performed, but the early development and verification of critical lander subsystems would be invaluable.

The purpose of this paper is to discuss some of the pertinent mission design issues associated with MESUR. Some details arc given on the mission aspects of the network architecture studies. in addition, there is a description of the design trades that have been performed for Pathfinder and the resulting reference mission design.

NETWORK ARCHITECTURES

The purpose of the network architecture study is to take a fresh look at the entire MESUR network concept. The political and fiscal climate today is considerably different from when the original Ames design was developed, and so some modification of the network concept is warranted. The network science objectives are being reconsidered by the science peer committees (Mars Science Working Group, MESUR Science Definition 'Team) which advise NASA. Simultaneously, JPL is attempting to develop various mission concepts that address a range of potential science objectives. Each of these concepts is being evaluated in terms of the total program cost and risk. Unlike previous missions, the program life cycle cost includes both the development cost and the price of launch vehicles and mission operations.

One significant mission design activity in the architecture study has been to develop mission scenarios that minimize the cost and risk, Pertinent issues include the number and type of launch vehicles, the number of Earth-Mars launch opportunities required to complete the network, the interplanetary trajectory characteristics, and the available landing sites for each opportunity. Figure 1 shows a schedule of trajectory opportunities for Earth-Mars transfers between 1996 and 2003. In addition, geometry information is given for the Earth, Mars and Sun during the same period. Performance figures for the Delta 7925 launch vehicle are shown to illustrate the variability between opportunities, A sample mission scenario that can be derived from this figure is a modified Ames approach in which 16 landers are launched on four Deltas. One set of four landers is launched on a 'Type -4 trajectory in October 1998. Mars arrival occurs in April 2001, after one and a half revolutions around the Sun, An additional set of four landers is launched on a one year Earth gravity assist trajectory in February 2000. This trajectory is a one year resonant orbit around the sun which arrives back at the Earth exactly one year after launch. An Earth gravity assist can be performed to place the landers on a standard Type 2 transfer to Mars. The final eight landers are launched directly from Earth onto this same Type 2 in February 2001". The reason why the Earth gravity assist trajectory is used is so that only two Delta launches have to be peformed in 2001, rather than three. The advantage to this mission scenario is that all sixteen landers arrive at Mars within about six months of each other. As a result, the landers only need to survive on the surface for the required one Mars year, in the Ames baseline, the set of landers sent in 1999 has to last on the surface for three Mars years before the mission is completed. One drawback to this modified scenario, however, is that some of the landers have to spend three Earth years in space on the way to Mars, This is merely an example, however, of the process of developing alternative mission scenarios.

PATHFINDER TRAJECTORY DESIGN

Network architecture studies only represent a small fraction of the on-going design work at JPL. Most activity has been concentrated on the interplanetary trajectory design for the Pathfinder mission. Pathfinder is a design to cost project, in which the entire development cost is required to be less than $150M. As a result, there are very tight constraints on the capabilities of the spacecraft and ground system. These constraints translate into a set of basic requirements on the mission design. The most general of these are that launch occur in 1996 and arrival in 1997 (implying that only Type 1 or Type 2 transfers can be considered). Furthermore, since the spacecraft does not have significant propulsive capability, only ballistic transfers can be used.

The interplanetary trajectory design for Pathfinder is further constrained by the fact that the spacecraft enters the Mars atmosphere directly from hyperbolic approach, As a result, there is strong coupling between the entry characteristics and the interplanetary transfer. The Pathfinder flight system uses an aeroshell that is closely modeled after the Viking aeroshell. The ablative material used on this aeroshell has a maximum heating rate limit of 100 W/cm^2. This limit translates into a constraint on entry velocity (6.5 km/s at 125 km altitude) or arrival v-infinity (4.2 km/s). This v-infinity requirement significantly limits the possible launch and arrival dates.

Additional design requirements are imposed on the interplanetary trajectory because of the landing site geometry. Pathfinder uses a ballistic entry and descent approach, so the geometry of the landing site depends direct] y on the approach geometry. Figure 2 shows a set of potential approach h yperbolas to Mars for a Type 2 transfer. A 11 of these approach h yperbolas have the same v-infinity vector, with varying t>-plane angles. If a constant entry angle is used for these hyperbolas, the resulting landing sites form a continuous minor circle around the planet. in this case, the circle has a maximum northern latitude of 50° and a maximum southern latitude of 60°. Sites outside of this range cannot be reached with this launch and arrival date combination (with the given entry angle). The geometry of the sun and Earth at arrival is also constrained by the arrival date. The crosshatched regions of the Martian surface represent areas that arc in the dark. The Pathfinder spacecraft is solar powered, so it is extremely desirable to land in the daylight. All the trajectories in Figure 2 land in the daylight, but nighttime landings occur if different b-plane angles arc used. The geometry of the Earth and sun at arrival is onc of the major discriminating factors between trajectory options.

REFERENCES

1) Mars Environmental Survey (MESUR) Science Objectives and Mission Design, NASA Ames Research Center, July 1991.

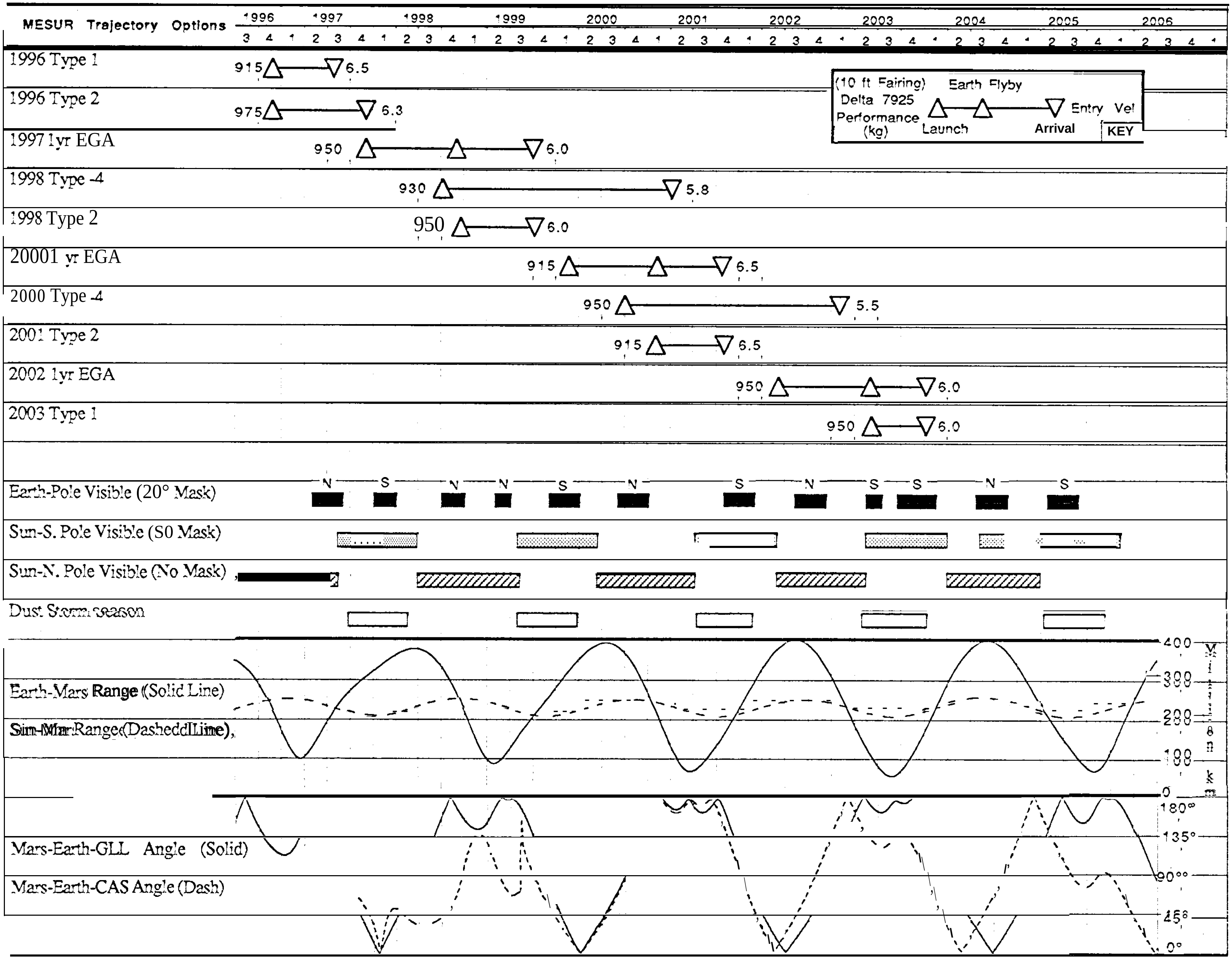

Figure 1. MESUR Network Trajectory Options

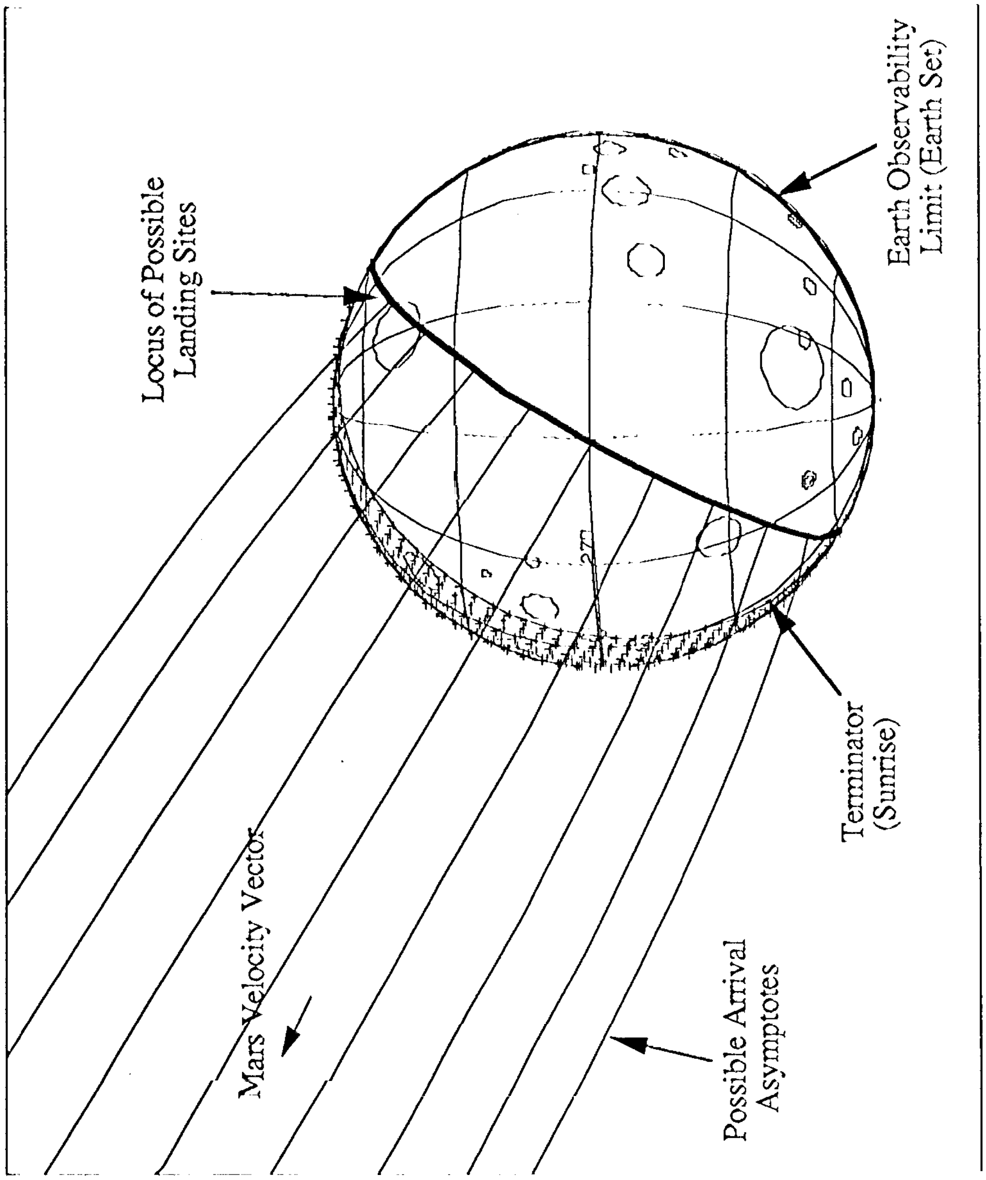

Figure 2. Mars Direct Entry Approach Geometry